

PARIS GREEN IN THE ERADICATION OF *ANOPHELES GAMBIAE*: BRAZIL, 1940; EGYPT, 1945¹

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INTRODUCTION. In March 1930, *Anopheles gambiae*, probably the world's most efficient vector of malaria, was found at Natal, Brazil, (Shannon, 1930). Its arrival was associated with the development of rapid communications with Europe by way of Dakar. Although the breeding of *gambiae* when discovered was less than 1 sq. km. in extent, a serious outbreak of malaria occurred in the following month. The severity of this outbreak was such that the Health Department had to distribute "food as well as quinine."

Twelve years later, in March 1942, severe outbreaks of malaria in Upper Egypt signaled the invasion of Egypt by *gambiae* coming from the Sudan. This invasion was associated with greatly in-

creased traffic into Egypt from the south, due to wartime difficulties of shipping in the Mediterranean. In the fall of 1942 *gambiae*-transmitted malaria struck as far north as Asyut, some 320 kms. from Cairo.

Gambiae was eradicated in Brazil in 1940 (Soper and Wilson, 1943), after a sojourn of 10½ years in the country; in Egypt eradication came in 1945, (Shousha, 1947/48), three years after the invasion occurred. The basic method used in each country was a straightforward chemical attack with paris green. Victory in each country came only after unnecessary and costly delays. These delays can be attributed to lack of vision, lack of courage, lack of salesmanship, and lack of administrative experience.

Through a series of coincidences I participated in the delays in eradicating, and in the eradication of, *gambiae* in both Brazil and Egypt.

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LOCAL ERADICATION AT NATAL, 1931-32. I returned to Brazil on March 20, 1930 to become the Director of the Cooperative Yellow Fever Service maintained by the Government and the Rockefeller Foundation; *gambiae* was found at Natal three days later.

On April 28 I visited 40 houses at Natal, seeing one or more persons ill in practically every home; some entire families were sick, with none able to procure and prepare food. This was malaria in a new dimension, a dimension which required "food as well as quinine." *Gambiae* is not just another vector of malaria, but one which transforms malaria into a great epidemic scourge, ranking as a killer with cholera, plague, smallpox, typhus, and yellow fever. The severity of the initial *gambiae*-malaria outbreak in Natal and the small size of the breeding area of the new invader inevitably stimulated discussion of and hope for species eradication.

With a sense of responsibility engendered by knowledge of the situation, I discussed the eradication of *gambiae* with the State Director of Health, with the Governor of Rio Grande do Norte, with the Director of the National Department of Health, and with my chief, the Director of the International Health Division of the Rockefeller Foundation. Action by the State Director of Health depended on the decision of the Governor, who was unwilling to authorize flooding the tidal flat where *gambiae* were breeding by opening the dike to let in salt water. The Director of the National Department of Health recognized the eventual threat of *gambiae* to other states, but the Federal Government declined to put pressure on the state government in a presidential election year. My chief in New York suggested I was fully occupied with the reorganization of the Yellow Fever Service and had better leave the *gambiae* problem to the Brazilians.

Malaria in Natal died down during the dry season of 1930, but with the onset of the rains in January 1931 an even more severe outbreak occurred. This was expected since a December survey showed

gambiae had spread to the limits of its initial breeding area, a total of some 50 sq. kms.

The presidential election was followed by successful revolution with interruption of the normal relationship existing between the states and the Federal Government. The appeal for aid from Rio Grande do Norte to meet the epidemic of 1931 found the new Federal Government unprepared; the National Director of Health requested the Yellow Fever Service to assume responsibility for the *gambiae* problem in Brazil. Considering the needs of the Yellow Fever Service and the negative attitude of the Foundation, I refused to consider this proposal. On further insistence of the Director, however, I agreed to an emergency malaria prevention program in Natal for a six-month period; this would enable the Government to prepare its own anti-*gambiae* program.

The Yellow Fever Service actually began the application of paris green to the infested area early in March 1931, just a year after it had been found. In accord with current practice, paris green was mixed 1 to 2 percent with a suitable diluent before delivery to the field for application. Malaria receded and the number of *gambiae* to be found in the houses declined rapidly; only 11 were found in 8,393 houses searched in 10 weeks between July and the middle of October.

The Government met its obligation by appointing a malariologist as Director of the State Health Service with a special Federal budget to be devoted to malaria in Rio Grande do Norte. The State Service assumed the responsibility for the paris green program on October 14, 1931; the application of paris green was only until mid-April 1932 when the special budget was spent.

The 1931-32 attack on *gambiae* with paris green resulted in its complete disappearance from Natal; it has not since been found breeding there.

Gambiae ESCAPES TO THE INTERIOR, 1931. In the meantime, in June 1931, a sharp outbreak of malaria at São Bento, 180

ms. from Natal, had shown that *gambiae* was no longer limited to its original point of entry. In the following months a dozen places between Natal and São Bento were found infested. Although the invaded area was not highly favorable for *gambiae*, my July diary shows that the extension of *gambiae* so far to the interior had convinced me that eradication was no longer possible. In retrospect this negative attitude was most important; it may well have been responsible for the failure to realize that the scarcity of *gambiae* in Natal after July was a prelude to its eradication there. It may well have been responsible for the failure, once *gambiae* had been eradicated at Natal, to organize a drive to clear it from the interior of the State.

The elimination of *gambiae* at Natal and the effects of the severe drought of 1932-33 on *gambiae* in the interior quieted the public demand for relief from malaria; everyone relaxed, if fearfully, since *gambiae* continued to appear among mosquito collections made in the interior by the Yellow Fever Service. Thus five years passed before *gambiae* moved into more favorable areas.

INVASION OF CEARÁ, 1937. In 1937 *gambiae* moved to better-watered areas in Rio Grande do Norte and passed over the frontier into the State of Ceará; the resultant outbreaks of malaria were not immediately sufficient to cause a reaction on the national scene. The picture changed rapidly during the rainy season of 1938, when newspaper accounts appeared of large State expenditures on relief measures because of malaria in the Jaguaribe River Valley. (Again the theme of epidemic malaria requiring "food and quinine.")

The 1938 epidemic in Ceará was especially devastating; infection rates were 100 percent in some areas with high mortality and complete economic paralysis. In August the Federal Government created a special Malaria Service with an emergency budget. When the chief of this Service reached the field, it was obvious that the funds allotted were grossly in-

adequate; that the epidemic situation and the continuing expansion of the *gambiae*-infested area could be met only by an experienced administrative service. The suggestion was made again in 1938, as it had been in 1931, that the Yellow Fever Service should take the responsibility for the *gambiae* problem.

THE GOVERNMENT OF BRAZIL AND THE ROCKEFELLER FOUNDATION JOIN FORCES AGAINST *gambiae*, 1939. The situation in 1938 was quite different from that of 1931. Although *gambiae* now occupied a triangular area almost 500 kms. on the side instead of a few square kilometers, the forces which could be brought against it were far superior both administratively and psychologically.

In 1931 the Yellow Fever Service was preoccupied with *Aedes aegypti*-transmitted yellow fever still to be found in towns and villages in the north and in the south of Brazil; the memory was still fresh of the failure to eradicate yellow fever as planned and of the reinfection of Rio in 1928-29; still fresh in mind was the 1927-29 failure to eradicate *Aedes aegypti* in a single town after an intensive attempt to do so. In 1931 the Yellow Fever Service, which had been limited to a number of the larger cities of the north, had just assumed the responsibility for yellow fever throughout Brazil, except in Rio. The Yellow Fever Service was still operating under varied state regulations. In 1931 many still believed that there was no reason to be perturbed over the introduction of another vector of malaria since Brazil already had its fair quota; it was also widely held that *gambiae* would not be able to establish itself in Brazil since there was no known instance of an *Anopheles* of one faunal region invading another.

By 1938 *Aedes aegypti*-transmitted yellow fever had disappeared; the Yellow Fever Service was operating throughout Brazil with the full confidence of the Brazilian Government, under a special national yellow fever regulation establishing adequate authority for anti-mosquito measures. Even more important was the

psychological change which had come with the progressive eradication of *aegypti* beginning in 1932-33. First proven in a number of large port cities, the eradication of *aegypti* had been extended in the following years to the suburbs of these cities and to infested towns, villages, and even rural areas. The experience in developing the administrative program for the eradication of *aegypti* had given the Yellow Fever Service a knowledge of meticulous administration and a confidence in its own capacity to apply this knowledge to other programs. Important psychologically also in 1938 was the knowledge that *gambiae* had definitely become established in Brazil, had reached favorable areas where progressive expansion of its range was imminent, and constituted a serious threat to the health and economic development of the tropics and subtropics of South, Middle, and North America.

In 1938 the Yellow Fever Service was far better equipped to meet the *gambiae* emergency than it was in 1931; furthermore, it was the only administrative agency able to undertake the eradication of *gambiae*. So, under the pressure of circumstances, without knowing exactly how the job could be done, the Rockefeller Foundation and the Ministry of Health of Brazil joined hands to combat *Anopheles gambiae*; the Malaria Service of the North East (MSNE) was created as a twin service through which the knowledge, skill, and discipline of the Yellow Fever Service, already experienced in the eradication of *Aedes aegypti*, could be applied to the *gambiae* problem.

ERADICATION OF *gambiae*, 1939-42. The administrative framework of the MSNE was created by the transfer of key personnel and equipment directly from the Yellow Fever Service.

During the early weeks, the classical methods of malaria prevention then in vogue were tested and proven ineffective. The efficacy of paris green larviciding had been demonstrated for a limited area at Natal, but there was no precedent for its use in area-wide species eradication. In planning for the anti-*gambiae* work, thou-

sands of large gunny sacks had been purchased for the transportation of paris green-dust mixture, without determining the source of a proper dust or the means of transporting the diluted insecticide to the rural areas where needed.

The successful use of paris green in the eradication of *gambiae* began only after Barber demonstrated mixing it with dust, soil, sand, or even pebbles at the site of application and broadcasting by hand. The most serious logistical problem was solved; abandoning the dust-gun with its need for a uniform powdered diluent, the MSNE made its inspector fully mobile and independent of supply lines. Armed with an empty pail, a small supply of paris green, a measuring spoon, and his hammock, he could move freely, even on foot, for days at a time, unhampered by weighty equipment and insecticide. From June 1939, the basic attack on *gambiae* was a straightforward chemical attack with paris green.

In retrospect, Barber's visit should have been unnecessary. Barber and Hayne had written in 1921: "We have tried certain mechanical means for distributing the dust such as the dust guns used in dusting arsenic on cotton plants but thus far we have succeeded best by simply throwing the dust into the air by hand."

The detailed administrative techniques developed by the Yellow Fever Service, which had led to the eradication of *Aedes aegypti* (Soper *et al.* 1943), were readily adapted to the *gambiae* eradication program.

By the end of 1939 considerable progress had been made in reducing the area of infestation; the threat of expansion had been almost eliminated. As the infested area became smaller, more workers were moved in from the cleared periphery; the year 1940 witnessed a continuing reduction of the *gambiae*-infested area, even during the rainy season. November 1940 was the last month in which *gambiae* was found in Brazil.

The MSNE continued a wideflung search for *gambiae*, both within the previously infested area and far beyond it dur-

another 18 months. The MSNE was disbanded at the end of June 1942.

ANOPHELES *gambiae* in Egypt, 1942-43. Six months later, on January 7, 1943, as a member of the United States of America Typhus Commission, I arrived in Cairo to learn that Egypt had been invaded by *Anopheles gambiae* the previous year. The fall months of 1942 had been marked by a disastrous epidemic of malaria, paralleling in severity the *gambiae*-malaria outbreaks seen in Brazil but on a much larger scale.

On invitation of the Under Secretary of Health, I visited the infested epidemic area; my report emphasized the threat of continuing epidemic malaria if *gambiae* were not eradicated. I explained that the "same factors which make *Anopheles gambiae* such a dangerous vector of malaria, namely, its tendency to breed in shallow sunlit pools without vegetation and its habit of resting and feeding in human habitations, make it highly vulnerable to simple frontal chemical attack." I stated that complete species eradication, although not easy, was "entirely possible with the careful meticulous application throughout the entire infested area of measures already known and demonstrated."

I recommended that an emergency Anti-*gambiae* Service be organized; that this Service be of temporary character, directly under the Minister of Health, and responsible only for "the prevention of the spread of *A. gambiae* to those parts of Egypt not already infested, and the complete eradication of *A. gambiae* from Upper Egypt; . . . that this Service should have adequate funds and necessary liberty of action to carry out the administrative measures necessary for the rapid discharge of these responsibilities."

The Service should not be responsible in any way for the study and treatment of malaria.

I insisted the Director be given full autonomy in the choice, appointment, and discharge of all personnel; have full freedom to determine how and where work should be carried out; and be able to requisition needed items, including techni-

cal personnel, from other branches of the Health Department.

My report was also submitted to the diplomatic and military authorities of the United Kingdom and the United States since Egypt was at that time occupied as an active theater of war. I appeared before the Middle East Medical Supply Commission recommending the allocation of shipping tonnage for the importation of paris green. This was approved.

I failed to convince interested British workers that eradication of *gambiae* was possible; I likewise failed to convince the Egyptian authorities that they should request the Rockefeller Foundation to participate in the attack on *gambiae* with experienced administrators from Brazil. Failing this, I left with the Egyptian workers the manuscript of the then unpublished report on "*Anopheles gambiae* in Brazil, 1930 to 1940" and a copy of the detailed manual of instructions of the Brazilian operation. (This manual had been carefully prepared after *Anopheles gambiae* had already disappeared from Brazil, as an historical record of the procedures used and in the hope that it might be useful later in *gambiae* eradication programs in Africa south of the Sahara.)

ANOPHELES *gambiae* in Egypt, 1944-45. I left Egypt in June 1943 and not until February 24, 1944 did I learn of Egypt's catastrophic epidemic of the fall of the previous year. Then I saw at Naples, in the United States Army news sheet *The Stars and Stripes*, a British denial of the Egyptian charge that the occupation forces had so depleted the country's food supply that thousands had died of starvation in Upper Egypt. The British claimed that food stocks were adequate, that starvation had occurred because of paralysis of food distribution by an overwhelming epidemic of malaria. (Again emphasis on "food as well as quinine.")

On invitation of the Government of Egypt, I returned to Cairo early in May 1944 to make recommendations on malaria in the Nile Valley. The enormity of the 1943 catastrophe had made malaria a top political issue in which King Farouk him-

self became involved. The true measure of the 1943 epidemic will never be known; His Majesty told me a Royal Commission, after visiting the blighted areas, had estimated malaria deaths in two years at 130,000. Interest, finances, and authority would not be lacking for the attack on the invader.

After a week-long visit to the infested area, I rewrote for the Minister of Health the essential recommendations I had made 16 months before; I again offered the administrative assistance of the Rockefeller Foundation. These recommendations and offer were accepted, and in June 1944 a special Gambiae Eradication Service was created, independent of the Malaria Service, directly under the Minister of Health, and responsible only for the eradication of *gambiae* from Egypt.

Foundation participation began on July 15. Fortunately, the Egyptian Malaria Service had used the manual of instructions of the MSNE of Brazil in zoning the *gambiae*-infested area and had adequate personnel already in the field.

It had, however, failed to substitute paris green for oil in the attack on *gambiae*; the logistics problem for using oil had not been solved.

Beginning in July, the shift from oil to paris green was made as rapidly as possible, but the flood season was imminent and a great deal of malaria occurred in the fall of 1944.

In Egypt, as in Brazil, *gambiae* proved to be highly susceptible to paris green larviciding. The last *gambiae* in Egypt was found on February 19, 1945, just seven months after routine application of paris green began.

COMMENT. Thus the invasions of Brazil and of Egypt by *gambiae*, together covering a decade and a half, terminated with the invader rejected. Although the two campaigns were administratively and technically very similar, the geographical and psychological problems were quite different.

In Brazil *gambiae* was actively spreading at the periphery with an entire continent in jeopardy. The technique of

blocking this spread and of eradicating *gambiae* in the infested area was unknown. Not the certainty of winning but the cost of failure was the stimulus to action.

In Egypt *gambiae* had been successfully blocked at Asyut; the infested area was the narrow irrigated zone along the Nile surrounded by hostile desert; the limits of the problem were known as was its solution; no research was needed nor attempted; from the start the result could be foretold.

In Brazil work began with an inadequate budget; at a critical time during the first year there was considerable difficulty in financing operations. In Egypt instructions from the Minister of Health were from the beginning that *Anopheles gambiae* must be driven out. He said, "Go on spending!"

It is now 36 years since *gambiae* invaded Brazil and 24 years since it came down the Nile into Egypt. Brazil and Egypt are just as vulnerable to invasion by *gambiae* today as they were decades ago; many other regions of the world are equally vulnerable. Also it seems certain that some areas now suffering from *gambiae*-malaria could be more easily freed of this curse by eradication of *gambiae* than by other means. Malarialogists should fail to study the records of Brazil and Egypt as they face up to the challenge of African malaria. In Brazil, towards the end of the campaign, a small test area was cleared completely of *gambiae* in three weeks' time; in Egypt, *gambiae* was widespread in November but had disappeared before the end of February.

I have retold this story of long ago because it has lessons for each generation of conscientious public health administrators. I have told it in the first person because I have referred to killing costly delays due to lack of vision, lack of courage, lack of salesmanship, and lack of administrative experience; even the casual reader may identify examples of each.

References

- BARBER, M. A. and HAYNE, I. B. 1921. Arsenic as a larvicide for anopheline larvae. *Public Health Reports* 36:3027-3034.

HANNON, R. C. 1930. O aparecimento de espécie africana de *Anopheles* no Brasil. *Sil-Médico* 44:515-516.

SHOUSA, SIR ALY TEWFIK, 1947/48. The eradication of *Anopheles gambiae* from Upper Egypt, 1942-1945. *Bulletin of the World Health Organization* 1:309-352.

SOPER, F. L. and WILSON, D. BRUCE. 1943. *Anopheles gambiae* in Brazil, 1930 to 1940. The Rockefeller Foundation, New York.¹

SOPER, F. L., WILSON, D. B., LIMA, SERVULO, and ANTUNES, WALDEMAR SÁ. 1943. The Organization of Permanent Nation-Wide Anti-*Aedes aegypti* Measures in Brazil. The Rockefeller Foundation, New York.

1940 and of after-eradication measures continued to June 1942. The companion Portuguese volume, Campanha Contra o "*Anopheles gambiae*" no Brasil, 1939-1942 (F. L. Soper and D. B. Wilson, Ministry of Education and Health, Rio de Janeiro, 1945), covers particularly the final eradication campaign; it contains less text and more statistical tables.

¹This is the story of *Anopheles gambiae* in Brazil from its arrival in 1930 to its eradication in